

COURIER

SPECIAL ISSUE 1

July 1985

EMT-FRANZ GMBH

25 Years of Reverberation A Summary of EMT Contributions



The first EMT 140 Reverberation Unit left our manufacturing facilities in 1957. The very last unit was delivered only recently.

The first Epoch of artificial Reverberation

When the reverberation unit attained production readiness at EMT 25 years ago, no one suspected that it would help revolutionize the art of sound recording. Before the unit existed, the recording engineer depended on the acoustics of the recording space as a nearly constant parameter. At most, a reverberation chamber might have been at hand; this frequently consisted of a room in the basement in which a loudspeaker and a microphone had been installed. Such a chamber required a minimum volume of 50 m³, while 100 m³ was preferable. It was difficult to provide adequate isolation from extraneous sound, and the acoustical properties of the chamber were just as invariable as those of the recording studio. Because of these disadvantages, such installations were relatively uncommon. This ungratifying circumstance was eliminated by an ingenious invention of Dr. Walter Kuhl, a scientist at the erstwhile Rundfunktechnisches Institut (Institute of Broadcasting Technology) in Hamburg. He proposed suspending a large, rectangular steel plate at all four corners and using a suitable transducer to excite it with bending waves that corresponded with the signal to be reverberated (Fig. 2). Contrary to the case of airborne sound, such bending waves do not propagate with constant speed in solid bodies, but instead exhibit dispersive properties. As a result, the higher-frequency components of the signal propagate at a higher velocity

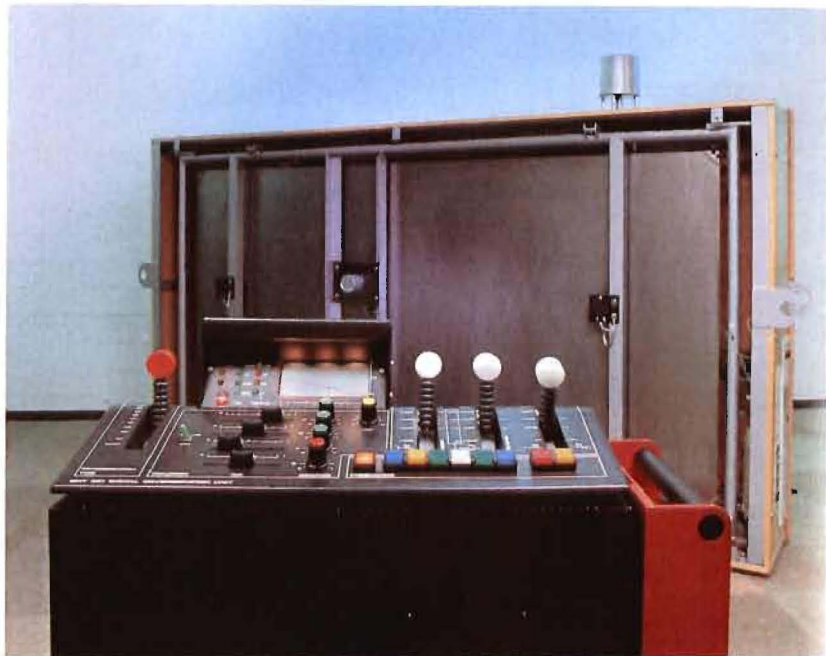


Fig. 1
25 years separate the manufacturing dates of these two units. Naturally, the EMT 251 Digital Reverberation System affords much more extensive capabilities for altering the acoustical event.

than those at lower frequencies. The bending waves are reflected at the sides of the plate in a manner similar to that of sound waves at the bounding surfaces of a room. In a plate excited with bending waves, the number of re-

flections increases much more rapidly as time continues than is the case in one-dimensional configurations, e.g., in springs. For the time segments of interest here, the ear detects nearly no difference between the increase of reflections in the two-dimensional plate and a three-dimensional room.

The vibrations of the plate are picked up by a piezoelectric transducer and transformed back into an electrical signal, which is now reverberated. Only one transducer was initially employed for this purpose, as indicated; a second

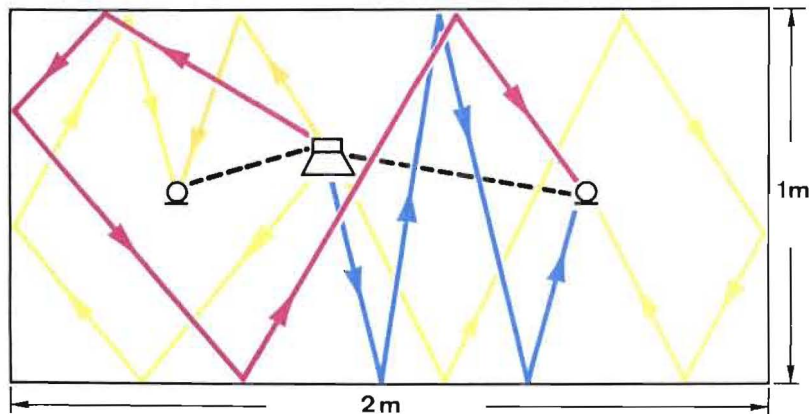


Fig. 2
Bending waves are reflected at the sides of the plate and arrive thus as reverberation over many paths at the sound pick-up transducers of the EMT 140 Reverberation Unit.

transduc
phonic a
transduc
ent dista
ducer in
distribute
countere

In contra
chamber
time cou
porous c
farther a
inhibits t
which ar
plate, th
energy.
withdraw
closer th
the vibr
manner,
adjusted
between

This instr
engineer
ation tim
tion acc
ctions. He
complete
characte
He did t
studio th
placing t
diate vic
addition,
acoustic
ments in
individua
individua
tape ma
practice
thus carr



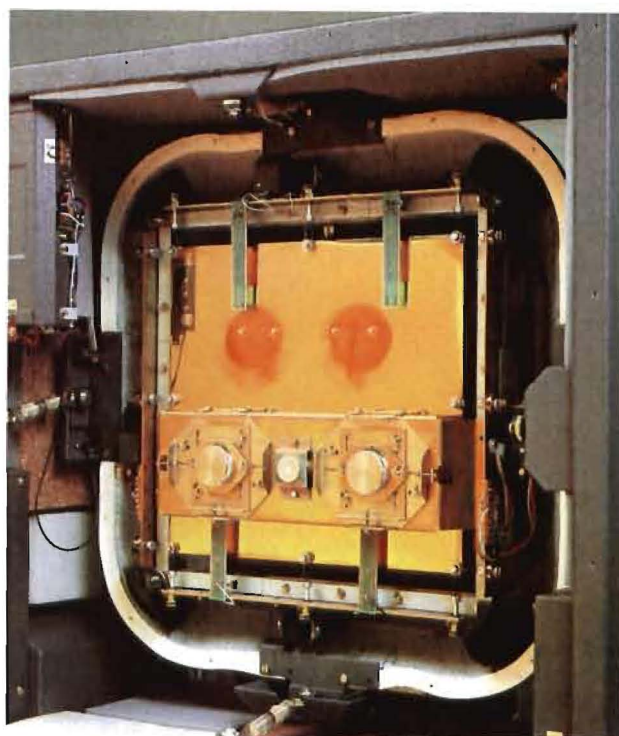
Fig. 4
A total of
25 years.
facilities.

transducer was later added for stereophonic applications. Each of the two transducers was positioned at a different distance from the excitation transducer in order to achieve a statistically distributed directional signal, as encountered in physical rooms.

In contrast to the earlier reverberation chambers, however, the reverberation time could also be varied by moving a porous damping panel nearer to or farther away from the plate. The panel inhibits the movement of air molecules which are excited by vibrations of the plate, thereby reducing their kinetic energy. This process, however, also withdraws energy from the plate. The closer the panel to the plate, the more the vibrations are damped. In this manner, the reverberation time may be adjusted manually or by remote control between 1 and 5 seconds.

This instrument enabled the recording engineer to vary the level and reverberation time of the requisite reverberation according to his artistic perceptions. He was even able to dispense completely with the reverberation characteristics of the recording space. He did this by selecting a recording studio that was as "dry" as possible and placing the microphone in the immediate vicinity of the sound source. In addition, he was able to neglect the acoustical interplay of various instruments in this space by recording the individual sound sources separately on individual tracks of a multiple-channel tape machine at different times. The practice of multichannel recording thus came into being, and it represents

Fig. 3
For the adherents of reverberation produced by analog means, the EMT 240 continues to be available.



the state of the art today, at least in the field of popular music.

This development has had not only artistic consequences but also significant economic advantages. If any instrument or group of instruments performs unsatisfactorily, the entire recording does not need to be repeated, only the faulty portion. The other participants in the recording session, who

are frequently highly-paid performers, are not required to wait idly during the interim. With the advent of stereo, an additional advantage of the new recording technique presented itself. When the individual portions of a recording were mixed together, the localization of the various sound sources could be altered in accordance with the desired total artistic impression. The two pick-up transducers of the reverberation unit delivered the non-correlated reverberation signals required for this purpose.

The EMT 140 Reverberation Unit was too large to be employed in mobile vans because of the plate dimensions of 1 x 2 meters and the size of the cabinet thus necessitated. The demand for a smaller unit consequently arose, but its fulfillment proved to be no easy matter. Only 14 years later, in 1972, could the EMT 240 Reverb Foil, with a 30 x 30 cm gold foil a mere 0.02 mm thick, be suitably developed for commercial production. This diminutive dimensions of the foil permitted installation in a metal housing consisting of two metal shells, which provided such a high degree of immunity to airborne and mechanical vibrations that the unit could be employed as required in mobile vans despite all incident acoustical disturbances. Operation was even possible adjacent to monitor loudspeakers at sound pressure levels exceeding 100 dB.

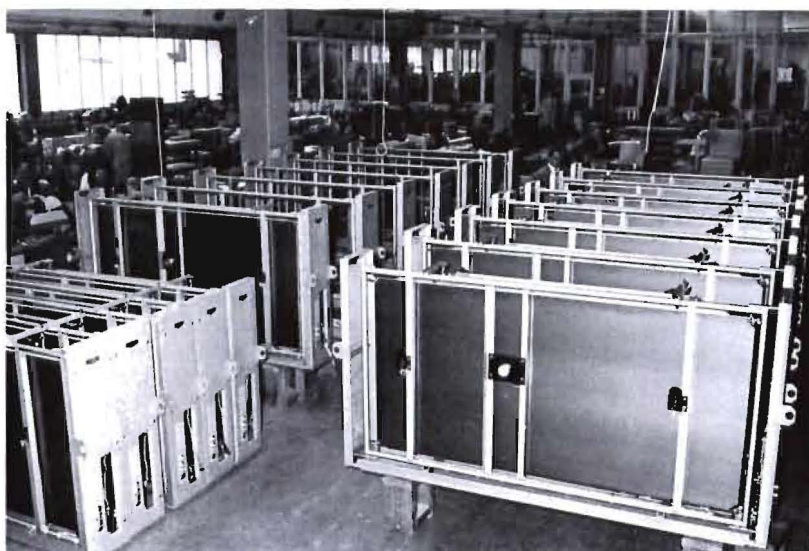


Fig. 4
A total of 4231 EMT 140 Reverberation Units were built by Gerätewerk Lahr in the last 25 years. Today, EMT 245 and EMT 251 reverberation systems are produced in these facilities.

Today, reverberation is produced mainly by extremely high-speed computers, which calculate each reverberation spectrum in an unimaginably



Dr. Eng. Walter Kuhl, the inventor of the reverberation plate, is visibly pleased that "his" unit was produced for a quarter of a century almost without modification. In our fast-paced age, that is likely to remain a rare exception.

brief period of time, and in which the reverberation parameters may be varied to a much greater degree. The techniques employed have been described in detail in an earlier EMT Courier (1) with the example of the EMT 250 Electronic Reverberator Unit. The progress of digital technology has since led to a second, improved generation of reverberation units: the EMT 251 Digital Reverberation System (2) and the EMT 245 Digital Reverberator (3). Their versatility and convenience in use has understandably resulted in a decline in requests for the large EMT 140 Reverberation Unit, so that the production may no longer be economically justified. Nevertheless, many recording engineers in the world do not wish to abandon the sound of reverberation produced by analog means, especially the "golden sound" of the EMT 240. This unit continues to be produced for them in undiminished quantities.

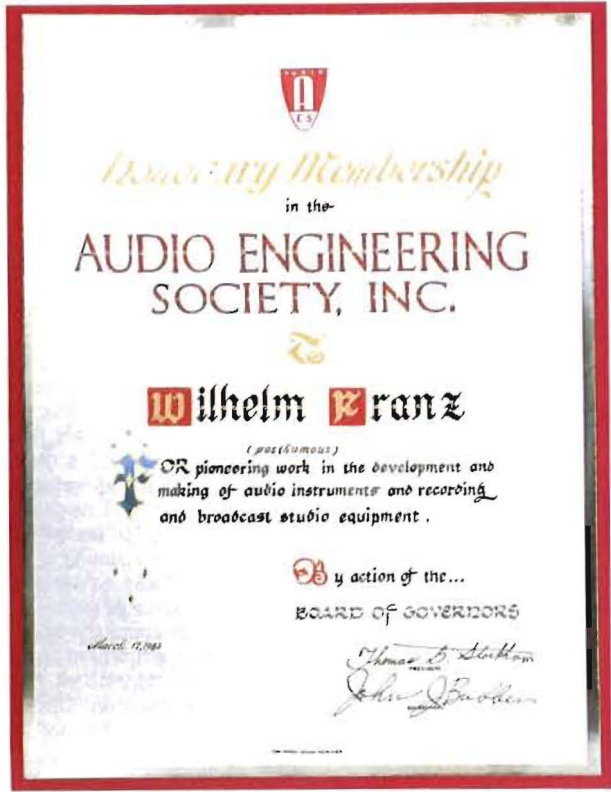
Still, one piece of news remains a delicacy. The final EMT 140 Reverberation Unit manufactured by EMT has arrived in a country that is among the leading proponents of digital technology in the

field of electro-acoustics: it was delivered to the Hitokuchizaka Studio in Tokyo.



The final reverberation unit has arrived at the Hitokuchizaka Studio in the progressive city of Tokyo, and its daily use confirms that the epoch of analog audio technology will not soon be coming to an end.

- (1) EMT Courier No. 26, June 1976
- (2) EMT Courier No. 35, February 1981
- (3) EMT Courier No. 36, April 1982



An honor has been bestowed by the Audio Engineering Society that is particularly eminent by reason of its exceptional rarity: Wilhelm Franz, the founder of EMT who passed away 12 years ago, has received this distinction posthumously for his pioneering achievements in our field of endeavor.

EMT Courier Special Issue No. 1
This special issue was compiled from different editions of the EMT Courier.
Proprietor, editor, and publisher:
EMT-FRANZ GmbH, D-7630 Lahr (West Germany)
Office: Bahnhofstraße 60, D-7634 Kippenheim.
Responsible for contents:
Dipl.-Ing. K.O. Bäder, Dr. Frank Hirsch, Lahr.
Printed by: Schütz, D-7630 Lahr.
Printed in the Federal Republic of Germany.
Any reprinting permitted only if reference is given.

KSE-506/2/1-S Printed in the Federal Republic of Germany

The solution may be achieved with a... The most... verberation... which 1... decrea... its origi... ment is... limited... missior... mental... scribes... and -3... sultant... Since ti... proves... is mea... center... series... may be... prehen... Time a...

While t... doubt... acousti... weighe... little re... ing a r... criterio... practic... Becaus... surpris... provide...

Reverberation

Acoust... noise d... do not... invari... in the e... mental... is to be... cease... a melo... maskin...

The tir... caying... maskin... tion du... vidual... differer...

as deliv-
studio in



arrived at
progress-
use con-
dio tech-
to an end.

376
ry 1981
382

g
(cep-
passed
hu-

ferent

Germany).
nheim.

hr.

ny
a is given.

Reverberation data obtained in a physical room are seldom identical with the settings employed to duplicate the same room. The question is thus often posed:

What's wrong with the Reverb Time ?

The following treatment is intended to clarify the relationship between reverberation measurement data and the subjective aural perception of reverberation signals.

The sound field of decaying reverberation may be described fairly accurately with appropriate measurement data. The most important quantity is the reverberation time, the interval during which the energy of the sound field decreases to one-millionth (-60 dB) of its original value. Since the measurement is restricted in practice by the limited dynamic range of the transmission channel (e.g., due to environmental noise), the IEC procedure prescribes that the range between -5 dB and -35 dB be evaluated and the resultant measurement value doubled. Since the reverberation time generally proves to be frequency dependent, it is measured at various third-octave center frequencies; in this manner, a series of data points is obtained that may be joined to form a single, comprehensive curve ("Reverberation Time as a Function of Frequency").

While the measurement data are undoubtable of great significance for the acoustical design considerations weighed by architects, they are of very little relevance in subjectively assessing a reverberation signal (the primary criterion for reverberation units in practical studio use).

Because this contention is likely to be surprising, the following elaboration is provided.

Reverberation Time and Reverberation Duration

Acoustical events can be masked by noise disturbances. Such disturbances do not only consist of signals which are invariably produced by noise sources in the electrical channel or by environmental effects. The sound signal which is to be reverberated usually does not cease abruptly but, e.g., in the case of a melody, continues and may act as a masking source.

The time which elapses before a decaying sound signal is covered by a masking source is called the reverberation duration. In this regard, two individual reverberation processes with different reverberation times may very

well exhibit the same reverberation duration (Fig. 1).

In order to achieve the same reverberation duration with process A as with process B, a relatively high reverberation level must be mixed in. This procedure may lead to an undesired result; a high-level reverberation component in the direct signal may convey the subjective impression that the sound source is more distant (Fig. 2). The desire to preserve a very direct sound may compel the studio engineer to mix in only a minimal reverberation component; in this instance, an "unnaturally long" reverberation time must be selected to achieve the same reverberation duration and therefore the same subjective impression.

In practice, the effect of a constantly changing masking source is particular-

ly noticeable at the conclusion of events. It is necessary to vary the amount of reverberation mixed in at the end of a piece, because the masking level decreases drastically, so that the reverberation duration (for constant reverberation time) increases.

In literature on the subject, the beginning of a reverberation signal is customarily identified as the event determining the reverberation time. This relationship holds true, however, only when a reverberation signal is heard alone. With the practice of mixing the direct signal with the reverberation, the beginning is very strongly masked by the direct signal, particularly when the mix-in level is low, as in the case described above. For this reason, the reverberation is in fact the quantity which determines the subjective reverberation time.

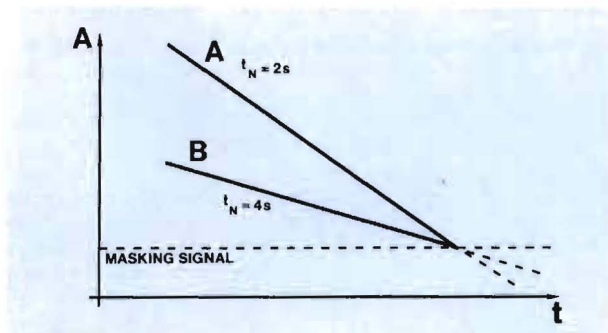


Fig. 1
Two reverberation
processes with different reverberation
times but the same reverberation
duration

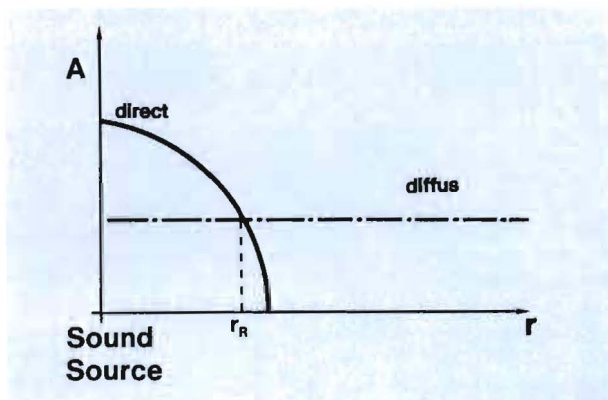


Fig. 2
Distribution of the
direct and the dif-
fuse components of
a sound field in a
room

Frequency Response of the Reverberation Time and the Fletcher-Munson Curves

Due to the masking effect occurring in the early part of the reverberation process, the subsequent portions are especially important for the listening impression. These usually occur in level ranges, however, in which the increased sensitivity of the ear plays an important role. As the loudness decreases, the ear becomes relatively more sensitive to higher frequencies, with the peak lying at approximately 5 kHz.

As a result, the higher frequency components are perceived much more intensely with a linear reverberation frequency response. The recording engineer is therefore obliged to attenuate the higher frequencies to maintain tonal balance. For this reason, all EMT reverberation units are provided with a high-frequency rolloff characteristic, which is switchable in the digital units, as well.

This effect is aided in nature by the fact that the absorbant property of air is more pronounced at high than at low frequencies. This characteristic is perceptible, however, only with long acoustical propagation paths in air. In studio practice, therefore, the first factor described above is of greater importance.

Direct Signal and Reverberation Component

The characteristics of the direct signal and of the diffuse reverberation signal components are illustrated in Fig. 2. The greater the radial distance from a sound source, the more the direct component is diminished. By contrast, the diffuse component increases, provided that the sound is propagated in a room with enclosing walls rather than in a free field.

For the studio engineer, this relationship means that the impression of distance may be manipulated for a sound source by altering the component mix.

An additional variable, the time delay between the direct and the reverberation components, also contributes to the impression created. The room size is determined not only by the reverberation time and its frequency response, but also by the time delay of the first incident reflection. In large rooms, a relatively long time elapses before first incidence. Conversely, a long reverberation time without delay does not simulate a large room, but instead a rather small chamber with extremely hard walls.

Fig. 3 Distribution in space and time of the individual reflections in a cluster

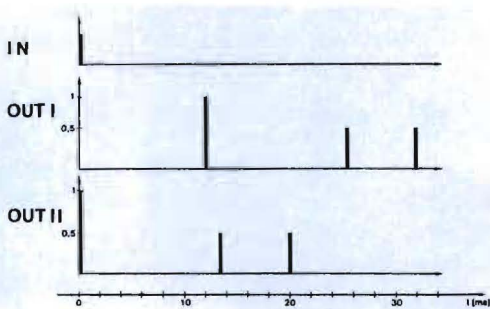
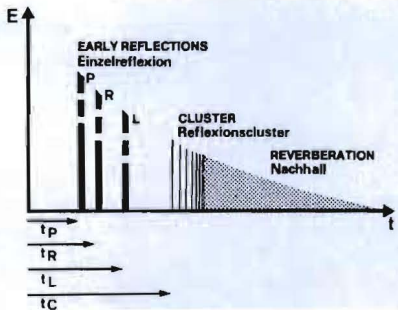


Fig. 4 Early reflections and beginning of reverberation with the EMT 251 Digital Reverberation System



Through an increased separation in time of the first reflection from the original signal, the masking effect is continuously decreased, that is, the direct/diffuse relationship in the first reflection becomes more definite. Since the first reflection can no longer be separated from the reverberation — both appear at the same output of the reverberation unit — the recording engineer cannot effect any additional differentiation with the console faders.

It is therefore important that this differentiation capability be afforded in the reverberation unit itself. For this reason, the newly developed digital units from EMT include amplitude controls for the early reflections. In descriptive literature, they are occasionally designated as "depth controls", an appropriate reference to the fact that the projected depth in the room, that is, the distance to the virtual sound source, is determined by these controls.

Adjustment in Time of Early Reflections

The adjustment in time between the original signal and the beginning of reverberation, or the so-called "early reflections" which immediately precede the beginning of reverberation, is necessary not only for simulating a certain room size but also for increasing the presence. In this regard, experienced studio engineers customarily select much longer delay times than what may actually be observed in physical rooms.

In concert halls, especially in those with good "listenability", it often happens that the first reflections in fact arrive quite early (e.g., within 20 ms). However, these reflections transport very little energy, and the time required for a sufficient number of reflections to provide a high average energy content may be very long. With units which produce reverberation artificially, the distribution of energy over time cannot be controlled. In order to locate the maximum energy at approximately the same point in time as in reality, very long delay times are required.

In addition, the adjustment in time of the reflections greatly influences the spatial breadth of the acoustical event. When a small difference in time (approx. 5 ms) is introduced between reflections in the left and right channels, the signal is afforded great spaciousness. Comb filter colorations are not observed with this method. Such differences between the channels are employed in EMT units, for instance, with the reflection clusters (Fig. 3). With the EMT 251 Digital Reverberation System, an intermediate reflection may also be added and likewise distributed with a small difference in time to both output channels (Fig. 4).

Further information concerning these interrelationships may be found in the article "Das Zusammenwirken von direktem Schall, ersten Reflexionen und Nachhall bei der Hörsamkeit von Räumen und bei Schallaufnahmen" by Dr. Walter Kuhl, published in the West German journal "Rundfunktechnische Mitteilungen", Volume 9, Number 3.

The des- tion as a With rev can pro-

The te- phone p- largely micropt ing pop verbera cording ally diff availabl unit. The number charact lected second the rec parame reverbe is fami- esses a the sec more fl more a simulat rations not exi- are par- tive in popular Reverb second reverbe to refe reverbe full pote Consec their ir reviewe

The At- tion of

Fig. 1 pi- tation of- The sou- rectly fr- reflecte- and the- petitive- delays a- process- time di- pulse s- lowed t- appear- expone-

The design objective of any reverberation unit is to simulate natural room reverberation as accurately as possible. Additional requirements may also be satisfied, however. With reverberation parameters which are separately adjustable over wide ranges, a unit can provide a multitude of individual room impressions.

EMT 245

Digital Reverberator

The technique of individual microphone placement ("close miking") has largely superseded the use of room microphones, particularly for recording popular music. The necessary reverberation must be added during recording or at mixdown. Two conceptually different design approaches are available for the required reverberation unit. The first provides a relatively small number of hardwired reverberation characteristics of specific rooms selected by the manufacturer. The second, alternative approach permits the recording engineer to select the parameters freely which influence the reverberation. Provided that the user is familiar with the acoustical processes associated with reverberation, the second approach naturally affords more flexibility. Not only may many more acoustically different rooms be simulated, but reverberation configurations may also be produced which do not exist in nature. These capabilities are particularly interesting and effective in producing special effects for popular music. The EMT 245 Digital Reverberator represents a unit of the second type, as do all EMT electronic reverberation devices. It is advisable to refer to the processes of natural reverberation in order to realize the full potential of the digital reverberator. Consequently, these processes and their interrelationships shall now be reviewed.

The Acoustical Field as a Function of Time

Fig. 1 provides a schematic representation of a sound source and a receptor. The sound is not only transmitted directly from one to the other but also reflected from the room walls, the floor, and the ceiling. It therefore arrives repetitively at the receptor with various delays and attenuations. In Fig. 2, this process is illustrated in an amplitude/time diagram for a single acoustical pulse signal. The direct sound is followed by individual reflections, which appear with increasing incidence and exponentially decreasing amplitude.

The area of rapid concentration constitutes the actual reverberation, which is consequently delayed with respect to the direct sound. The amplitude and the delay time of the early reflections influence the aural impression in various ways. All reflections increase the loudness of the direct sound but not necessarily its clarity, which is improved only by reflections which are delayed by less than 50 ms (corresponding to an indirect sound path of 17 m). An excessively short first delay should not be selected, however. Depending on the amplitude, very early reflections may cause undesired tonal colorations or directional errors.

The Subjectively Perceived Room Size

Reflections delayed by 20 to 50 ms determine the perceived room size.

The longer the first reflection is delayed, the larger the room is perceived to be. Conversely, the sooner the reflection arrives, the smaller the room seems. Reflections delayed by more than 50 ms may be perceived as echos and therefore should be employed generally only for special effects.

In addition to the delay time, the amplitude of the early reflections exerts considerable influence on the resulting aural impression. Increased amplitudes result in an enlargement of the perceived room, but the resulting sound impression is less transparent. Should the capability be available, however, to adjust the amplitudes of the early reflections, they may be selected so that the transparency of the sound will be preserved even with long delay times.

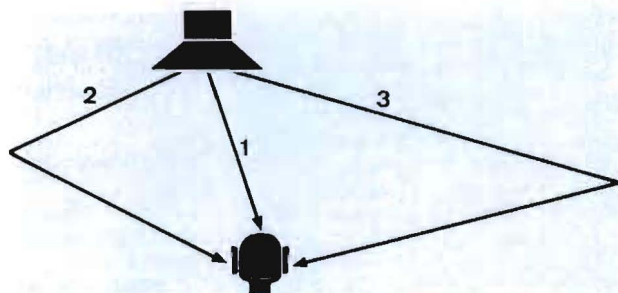


Fig. 1
Floor plan of a room
with source, receptor,
and sound paths

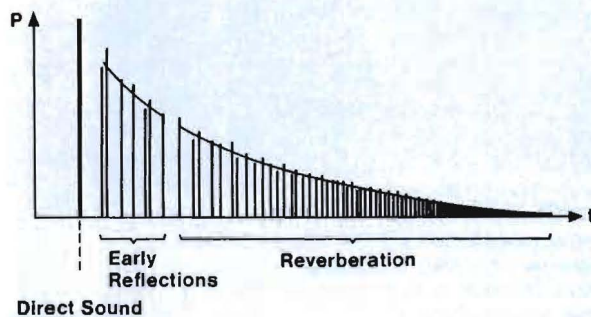


Fig. 2
 $E = f(t)$, with designation of individual components: acoustical event, early reflections, reverberation

The Reverberation Time

As already mentioned, the sound amplitude decreases exponentially as a function of time. With a (logarithmic) dB scale, conventionally employed in electroacoustics, the exponential function is a straight line, as shown in Fig. 3. When depicted in this manner, therefore, the sound level decreases continuously and linearly. The reverberation time is arbitrarily defined as the time during which the sound level decreases by 60 dB. This objective standard does not always reflect the subjectively perceived duration of a reverberation process. In contrast to the measured reverberation time, the subjective reverberation time is influenced by the loudness of the sound source and of noise disturbances. Whenever a physical room is to be simulated with a reverberation unit, reference values from room and architectural acoustics may be applied to select the optimum reverberation time. Such values clearly do not pertain to the production of special effects, particularly for modern music; instead, the desired reverberation must be determined experimentally in this case.

The Frequency Response of the Reverberation Time

The frequency response of the reverberation time exerts a significant influence on its quality. At low frequencies, large rooms often exhibit longer reverberation times and consequently deeply toned reverberation coloration. The high-frequency rolloff which is characteristic of all larger rooms is caused by the absorption of air. By contrast, rooms with large window areas convey not only a visual but also an aural impression of being "brilliant". Glass absorbs sound relatively poorly, even at high frequencies, and for this reason the high-frequency content of the reverberation is relatively pronounced. The frequency response of the reverberation time in a physical room is shown in Fig. 4.

Operation of the EMT 245 Digital Reverberator

The front panel of the EMT 245 Digital Reverberator includes operating controls for adjusting all reverberation parameters. The most prominent control knob (Fig. 5) permits the reverberation time to be selected in sixteen steps between 0.4 and 4.5 sec. Optimum reverberation times generally cannot be determined, because the requirements placed upon them are quite complex, changing according to the nature of the acoustical event and the expectations of the listener. For vocal presentations, the requirement of in-

Fig. 3
 $P = f(t)$, logarithmic scale, with 60 dB approx. line

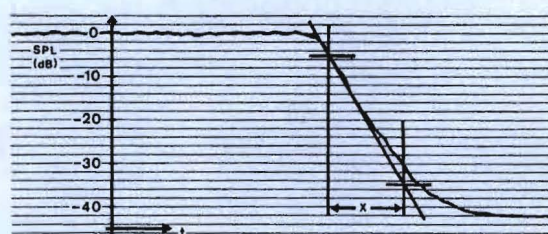
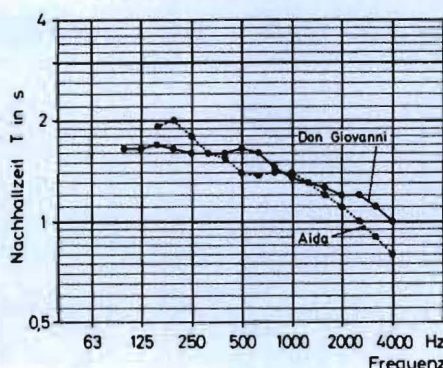


Fig. 4
Typical frequency response of reverberation time in a physical room



telligibility is frequently of prime importance, necessitating short reverberation times. Values between 0.4 and 1 sec. deliver satisfactory results in such cases. Reverberation times between 0.8 and 1.5 sec. are optimum for classical and modern music. Romantic music often requires times on the order of 2 sec. As a rule, the reverberation time in churches is noticeably longer, generally exceeding 2.5 sec. Naturally, no specification can be made for contemporary music productions, since in principle not the simulation of a room but a particular sound is required.

The frequency response graph (Fig. 6) next to the reverberation time selector clearly illustrates the capabilities of the EMT 245 Digital Reverberator for modifying the frequency response of the reverberation time. In modern concert halls and studios, architectural means have been employed to minimize frequency response effects of the reverberation time. Such environments are simulated by leaving both switches in the linear position. As already mentioned, the sound level is diminished at high frequencies in physical rooms due to air absorption. This phenomenon

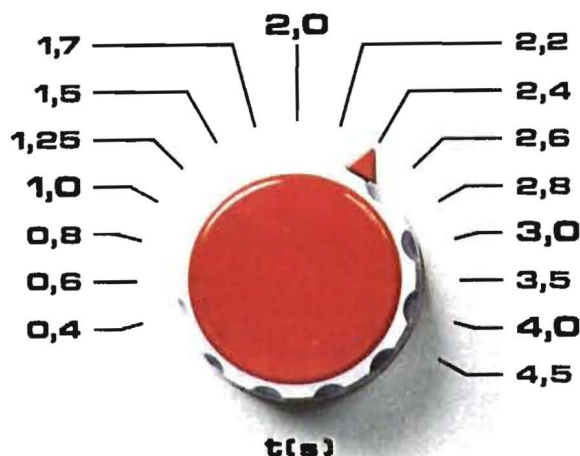


Fig. 5
Detail of reverberation time control

may be right-ha
ital Rev
stone w
exhibit
the bas
reverbe
mounte
ditions 1

36

24

12

0

R

mi

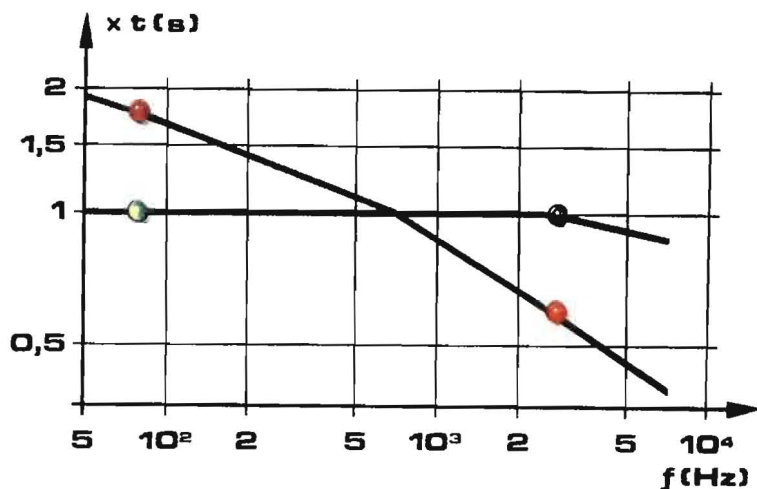


Fig. 6
Detail of frequency response graph of
EMT 245

- If an EMT 140/240 B Remote Control Unit is available from previous installations, it may be used to set the reverberation time. A special adapter board (Interface 2) is required for this purpose.
- The EMT 245 S Remote Control Unit (Fig. 9) is contained in a fader case of one-half normal height and is particularly suited for locations with limited space.

The EMT 245 S controls all functions of the EMT 245 Digital Reverberator through a single audio line from a remote location. All indications of operating states are communicated back through the same line. The remote control unit is built around an 8748 microprocessor, which calls up the settings in cyclic sequence and transmits the resulting information in serial form through the audio line. In addition to control and indicator elements, the EMT 245 S Remote Control Unit also employs a storage unit in which ten separate combinations of all parameters may be stored and recalled at any time. This storage unit, a CMOS RAM, is buffered with a lithium battery for retaining the stored information for approximately ten years.

may be taken into account with the right-hand switch on the EMT 245 Digital Reverberator. Deeply structured stone walls, such as found in churches, exhibit longer reverberation times in the bass region and a corresponding reverberation coloration. The switch mounted to the left enables such conditions to be simulated.

The interdependence of the early reflections and their amplitudes, as described above, is reflected in the locations of the rotary controls provided for their adjustment (Fig. 7). Because of the numerous parameters associated with microphone placement and selection, general rules for the combined effect of both controls cannot be formulated. After some practice, the proper adjustments may easily be made for simulating a room with pleasant acoustical characteristics.

Arrangement and Remote Control of the EMT 245 Digital Reverberator

As illustrated by the outline with physical dimensions in Fig. 8 (page 8), the EMT 245 Digital Reverberator may be readily installed in existing equipment cabinets, even where space is limited. Under some circumstances, however, it may be impossible to preserve optimum accessibility of all control elements.

In such cases, the EMT 245 Digital Reverberator affords various possibilities for remote control:

- All functions may be activated with switches and an appropriate number of parallel leads, without any additional equipment.

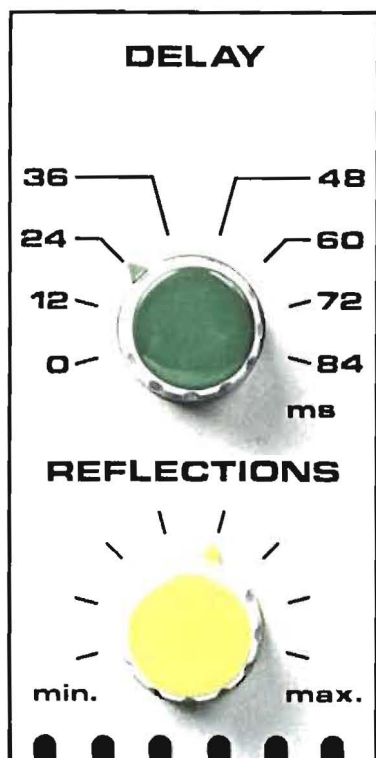


Fig. 7
Detail of Delay and Reflection Amplitude
controls



Fig. 9
The EMT 245 S Remote Control Unit

h (Fig. 6)
selector
ies of the
for mod-
e of the
concert
al means
imize fre-
ne rever-
ents are
itches in
dy men-
ished at
oms due
omenon

Fig. 5
reverbera-
e control

In combination with the EMT 245 S Remote Control Unit, the EMT 245 Digital Reverberator may be universally employed. The free selection capability of all reverberation parameters affords the appropriate flexibility. The storage provision for ten complete reverberation programs with push-button selection also permits the unit to be used as a reverberation system with fixed settings. This capability is advantageous when a decision must be made during mixdown between two reverberation characteristics using A/B comparison. In mobile use, an application for which the digital reverberator is particularly suited because of its compact dimensions, reverberation parameters selected for special purposes may be instantaneously switched in.

In contrast to other units, all such reverberation settings are not specified by the manufacturer; instead, they may be freely selected from the multitude of possible settings.

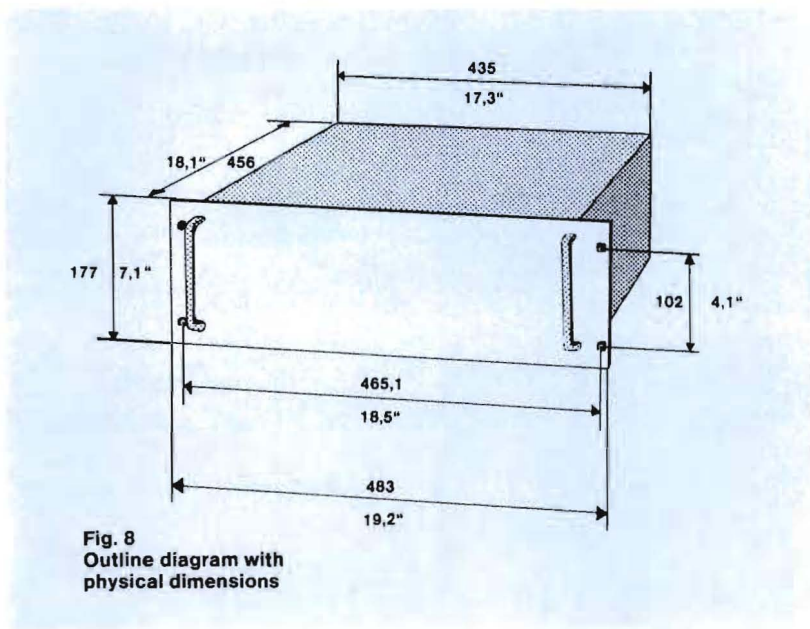


Fig. 8
Outline diagram with
physical dimensions

Colleagues not yet familiar with the techniques of digital audio sometimes ask us:

What actually is an algorithm?

This term is encountered again and again – in mathematics, in computer applications, and more recently in the field of audio, e.g., for the production of reverberation by digital means. Its definition may be simply expressed:

An algorithm is a finite number of precisely described instructions to be performed with given data in a certain order to determine a solution to a problem.

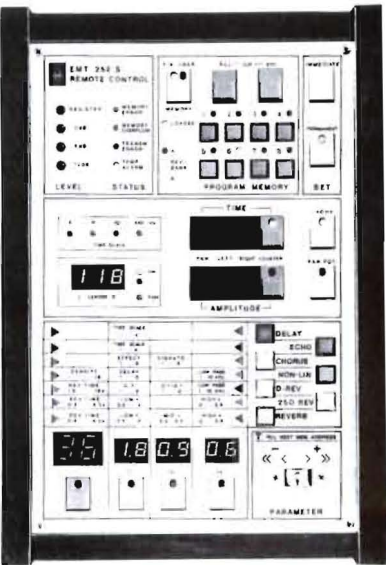
An algorithm for the production of reverberation is thus nothing else than all the instructions, or computing steps, with which the data at the input of the reverberation unit are used for calculating the output data in such a manner that the desired reverberation results.

The word "algorithm" may be traced back to a corruption in medieval Latin of the name al-Khwarizmi, the Arabian writer whose most famous treatise also gave us another term: algebra. He lived in the 9th century, at about the same time as Charlemagne. In a further work, translated with the Latin title **De numero Indorum (On Numbers of the Indians)**, al-Khwarizmi presented the rules for calculating with the numbers used by the Hindus. As time went on,

however, their contribution was forgotten, and al-Khwarizmi came to be considered the author of these rules. His Europeanized name, Algorithmus, became a synonym for the rules of addition, subtraction, multiplication, and division with the decimal system of numbers adopted from the Arab world.

One very significant improvement afforded by this numerical systems was, incidentally, the introduction of a symbol for zero, which did not exist in the Roman system.

The proponents of the new methods of calculation were called algorists, while supporters of the classical system were known as abacists after the Roman calculating instrument, the abacus.



It is an interesting fact of experience that reverberation sounds different when it has been calculated differently. Various algorithms distinguish the reverberation programs of the EMT 250 Electronic Reverberator Unit from those of the EMT 251 and EMT 252 Digital Reverberation Systems. The program of the EMT 250 is now also available for the EMT 252.

E
Di

Fig. 1 BI

EMT 251

Five years have passed since EMT introduced the EMT 250 Electronic Reverberator Unit, the first and, for a long time, only unit of its kind in the world. Since then, many new developments have been made in the field of semiconductor technology, particularly in Large Scale Integration. It has therefore become appropriate to replace the discrete processor of the EMT 250 with an integrated configuration. The advantages: more natural reverberation with nine adjustable discrete reflections and a full audio bandwidth, as well as new sound effect programs by higher clock frequency and larger memory capacity.

Digital Reverberation System

Microprocessor controlled with graphic display of reverberation parameters



Although modern microprocessors afford high-capacity performance, their operating speed is about ten times too slow for audio signal processing. A single microprocessor is therefore not capable of satisfying the requirements placed on a reverberation unit.

A solution to the problem is provided by a program architecture based on the use of a number of microprocessors. Computations which would be conducted serially by a single microprocessor in slow control applications are distributed here among a group of processors. This technique results in a system which not only is faster than its predecessor but also enables more versatile programs to be included. It also has been possible to raise the sampling frequency, significantly increasing the transmission bandwidth. New, highly integrated components

allow the use of a 16 bit digital language for the analog/digital conversion processes in both directions. A substantial improvement in the signal-to-noise ratio is thereby achieved.

The result of these developments is a digital reverberation unit with technical specifications which greatly exceed those of its predecessor, and with an expanded reverberation program.

Block Diagram

The unit executes all programs according to the block diagram of Fig. 1.

The audio input is balanced and exhibits conventional studio characteristics. Following the input stage, a low-pass filter prevents frequency products from forming between components of the input signal and the sampling fre-

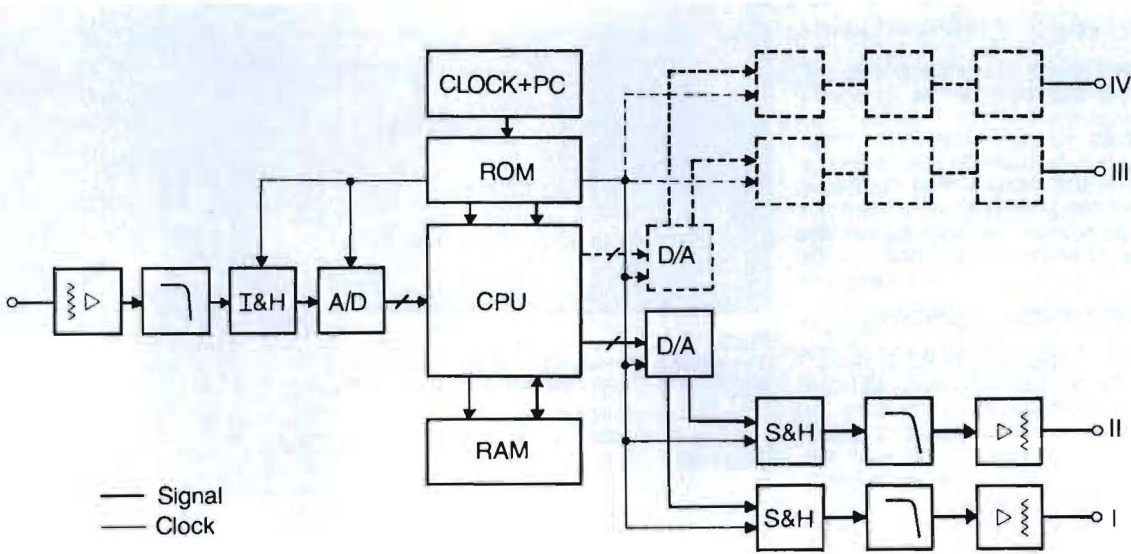


Fig. 1 Block diagram of the EMT 251 Digital Reverberation System

quency. An integrate-and-hold circuit and the analog/digital converter are arranged after the filter. According to the sampling theorem, the sampling frequency must be at least twice as high as the highest frequency to be transmitted. In the EMT 251, therefore, a frequency of 32.75 kHz is employed. The program signal, now converted into a uniform 16 bit code, is routed to the processor itself.

The type and sequence of operations is determined by the Read Only Memory (ROM). Intermediate results are stored in a Random Access Memory (RAM). The processor is followed by a digital/analog converter, from which two non-correlated signals appear. These are conducted through sample-and-hold circuits and low-pass filters to the line output amplifiers. The four-channel version, available as an option, contains a second D/A converter with corresponding sample-and-hold circuits, low-pass filters, and output amplifiers.

Data Integrity

Data integrity and error recognition are achieved in the EMT 251 using so-called CCRC's (Cyclic Redundant Check Codes). Check bits are added to data blocks of a certain length, enabling errors to be recognized and corrected. The effectiveness of the data-checking procedure is expressed by the Hamming distance. (The concept of Hamming distance is explained in the "EMT Courier" No. 32, May 1977, page 5.) A Hamming distance of 4 has been realized in the EMT 251 Digital Reverberation System; that is, any single bit error within a data block can be located and corrected. If two errors occur, they will be signaled but not corrected.

An error signal is indicated by an LED on the operating panel.

The error-detection capability also allows the localization of an error and thus the indication of defective chips in the RAM memory. Replacement of a defective chip eliminates the source of recurrent errors.

The Reverberation Program

The total storage time of the EMT 251 Digital Reverberation System has been increased to allow the production of a number of discrete reflections with a combined length of up to 120 ms in addition to the pure reverberation. Three of the reflections may be individually adjusted for time and amplitude. One each is assigned to the right and left channels, while the third can be routed to either channel through a panorama potentiometer. The delay times are se-

lected with individual linear potentiometers, the amplitudes with rotary controls.

A fourth linear potentiometer controls the delay of a group of reflections with fixed relationships to one another, known as a reflection cluster, and determines the initiation of the reverberation program in time. The cluster consists of six individual reflections with decaying amplitude and fixed temporal relationships that determine the transition of discrete reflections to reverberation. The corresponding amplitude control potentiometer determines the proportion of direct to reverberative sound at the beginning of reverberation, thereby establishing the reverberation radius. This capability thus enables the control of an essential recording parameter which previously had remained fixed.



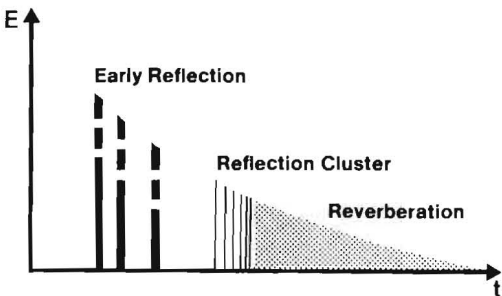
Fig. 3
The selected frequency response of the reverberation time and the amplitude/time distribution of the first reflections are identifiable at a glance on the display of the EMT 251.

Display

An additional new feature is the comprehensive indication of all selected parameters on a liquid crystal display.

The frequency response of the reverberation time as well as the amplitude-time distributions of the first reflections are indicated simultaneously by two curves. The user can therefore inform himself of the selected values at a glance.

Fig. 2
Distribution of reflections as a function of time with the EMT 251



A time diagram can be produced for the entirety of reflection amplitudes that very nearly approximates the conditions encountered in natural rooms.

The reverberation time itself can be adjusted between 0.4 and 4.5 seconds. In addition, the magnitude of the reverberation time can be varied over a wide range as a function of frequency, expressed as a factor of the basic reverberation time:

- for bass frequencies (300 Hz), a factor of 0.5 to 2;
- for midrange frequencies (4 kHz), a factor of 0.2 to 0.85;
- for treble frequencies (8 kHz), a factor of 0 to 0.85.

Special

In addition, consider

Chorus

This program voices (based on expression partially with different when all the same placement from the phone a of the v position small rel and bea natural times, p large so of Fig. 6 tion of t program through various continuous signal g quant le



Fig. 5
The individual distribution resulting in



Fig. 4 The control panel of the EMT 251

Special Programs

In addition to the reverberation program itself, the EMT 251 is provided with a considerable number of special programs for the production of particular effects.

Chorus

This program produces a multiplicity of voices or instruments. The effect is based on the recognition that the impression of a large sound source is partially due to individual sound signals with different propagation times. Even when all the musicians of Fig. 5 play at the same time with the microphone placement shown, the sound waves from their instruments reach the microphone at different moments because of the various distances necessary in positioning the musicians. In addition, small relative differences occur in pitch and beat. These effects, together with natural differences in propagation times, produce the impression of a large sound source. The block diagram of Fig. 6 depicts the electronic simulation of these processes in the Chorus program. The signal is conducted through four delay circuits with the various delay times $t_1 \dots t_4$, which are continuously altered by four random signal generators $k_1 \dots k_4$. The subsequent level controls $A_1 \dots A_4$ allow the

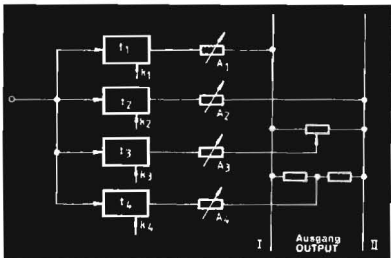


Fig. 6 Block diagram of the Chorus program

delayed signal to be mixed in such a way that the levels fall with increasing delay time.

The provision of the required level controls represents a significant advantage over the EMT 250 predecessor. With that unit, it was necessary to occupy four inputs of the mixing console to realize the same control function.

Non-Lin

If an acoustical event is repeated within a very certain range of time, the ear does not detect the repetition but rather perceives an increase in loudness because of the increased energy content. This effect is preferred for compressing audio signals. In driving power amplifiers and radio transmitters, however, it also affords the advantage of increasing the volume without raising the required power. Previously, the necessary signal delay was accomplished with a fixed propagation time.

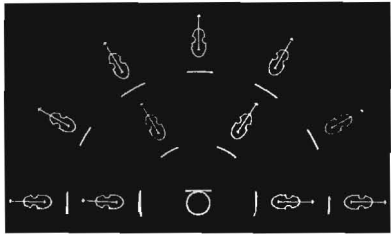


Fig. 5 The individual sound sources lie at different distances from the microphone, resulting in different propagation times.

This method, known as Automated Double Tracking (ADT), has the disadvantage that the processed audio signal sounds somewhat unnatural. The Non-Lin program of the EMT 251 avoids this difficulty by employing statistically distributed delay times, i.e., reverberation. By combining two reverberation processes, the reverberation is barely diminished over an interval of 0.5 seconds; afterwards, it decays rapidly. In this manner, the impression of excessive and thus disturbing reverberation is prevented.

Delay Program

The original signal appears at both outputs with as many as nine separate delay times. Three of the delayed signals may be individually controlled for time and amplitude and are assigned to the left or right channel or to the pan pot for stereo positioning. The remaining delayed signals comprise the cluster which is also used in the reverberation program.

The maximum delay time is 480 ms: the amplitudes may be varied between 0 and 100 %.

Doppler-Reverb

With this program, the pitch of the perceived reverberation signal can be appreciably changed. An illusion is thereby created that the reverberated sound is moving within the room. The impression of shifting images is produced by utilizing the Doppler effect.

Space

This sound effects program affords a reverberation time of maximally 18 seconds. The high-frequency control may be used to alter the frequency response and coloration. Such long reverberation times do not occur in our natural environment, and since the program is often used for science fiction productions, it has been named "Space".

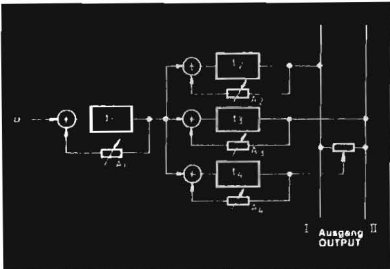
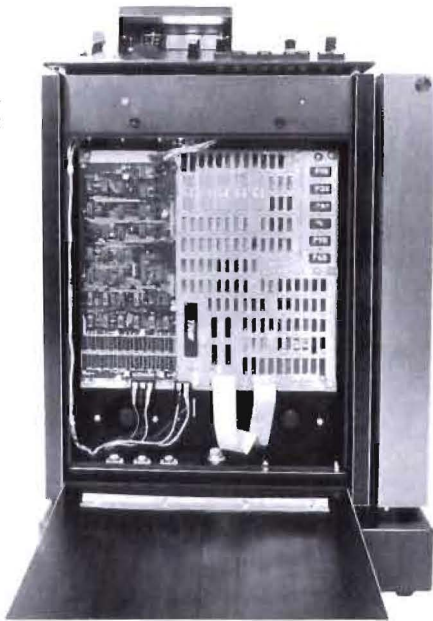


Fig. 7 Block diagram of the Echo program

Echo

The Echo program is implemented by loops which are variable in time between 0 and 440 ms and are adjustable for 0 to 60 dB attenuation per reflection. A main loop is followed by three auxiliary loops, thus enabling different effects to be selected for each of the two channels.

Fig. 8
The digital board is located behind the front panel of the unit.



Constructional Details

The appearance differs little from that of the predecessor. The form of a free-standing unit with switching levers has proven to be extremely practical, as has the arrangement of system components (Fig. 8). The power supply is located in a chassis at the bottom of the unit and is shielded to prevent disturbances of the sensitive electronics. The analog and digital sections are mounted in the center of the unit and separated from each other by an inter-

nal partition. Both side panels may be opened, affording good accessibility to all components (Fig. 8 and 9). The external panels are made of black anodized aluminum for dissipating heat from the interior of the unit. On the narrow right-hand side, the heat sink for the control circuitry is located together with the operating controls. The EMT 251 Digital Reverberation System is provided with a mains filter and with filters at the audio inputs and outputs — as are all new digital units from EMT.

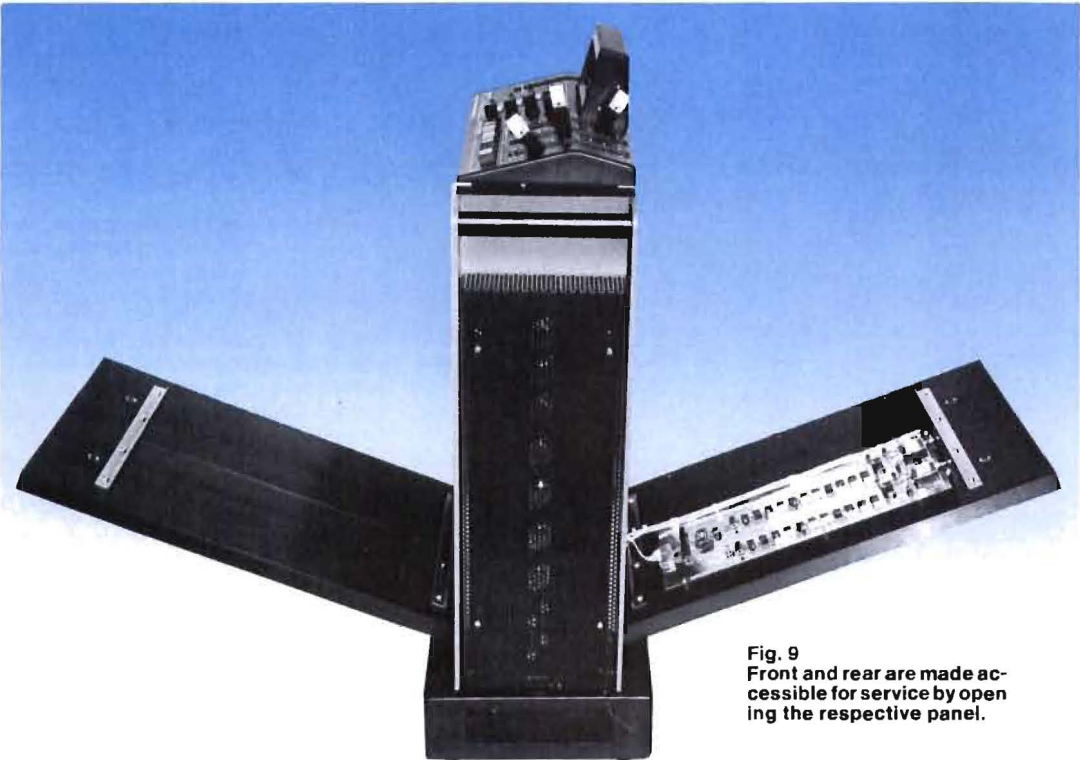


Fig. 9
Front and rear are made accessible for service by opening the respective panel.

Remote Indication

All program parameters can also be selected by a remote control button. In addition, the unit can be used as a remote control for a computer system during

Remote Control and Remote Indication

All programs and the reverberation parameters of the unit are not only selectable by remote control, but they can also be stored as preset values in a potentiometer array. In this manner, optimum adjustments for a particular application can be recalled by push-button. The DISPLAY lines also appear on a multiple connector, allowing an additional indicator to be located anywhere in the control room. The selected parameters can be stored in a computer or recorded on tape through a dc interface. The unit can then be controlled from the computer or tape during mixdown.



Fig. 10 The connector board of the EMT 251 with remote control and remote display

Literature

(1) Bellis, F.A., "A Stereo Digital Sound Recorder"; BBC Research Development Report PH-97, 1972.
(2) Nakajima, H., and T. Doi, Y. Tsuchiya, A. Iga, "A New PCM Audio System as an Adapter of Video Tape Recorders"; Preprint 1352 (E-11), 60th AES Convention, 1978, Los Angeles.

A Brief Chronicle of EMT Artificial Reverberation

Before the development of reverberation units, it was possible to obtain additional reverberation only by using an appropriate chamber.

1957 EMT introduced the EMT 140 Reverberation Unit, which was developed in close cooperation with Dr. W. Kuhl and the Institute for Radio Technology (IRT) in Hamburg. The unit employed a steel plate 2 m² in area and 0.5 mm thick on which bending waves were produced by a dynamic transducer. This was to remain the only reverberation unit of studio quality in the world for the next ten years.

1961 The EMT 140 Reverberation Unit was equipped with two microphone systems, enabling two largely uncorrelated signals to be obtained. The reverberation became stereophonic.

1971 EMT delivered the EMT 240 Reverb Foil. The surface of the vibrating 0.02 mm gold foil measured only 30 X 30 cm. The foil was contained in a double enclosure affording very high isolation from airborne and solid-borne disturbances, sufficient to allow placement of the EMT 240 even in mobile units or – at a sound pressure level of 105 dB – next to monitor loudspeakers.

1972 Digital technology entered the field of reverberation production. Previously, magnetic tape loops which were unreliable in continuous duty had represented the only way to produce artificial first reflections between the direct sound waves and reverberation. This function could now be discharged by the EMT 440 Electronic Delay System.

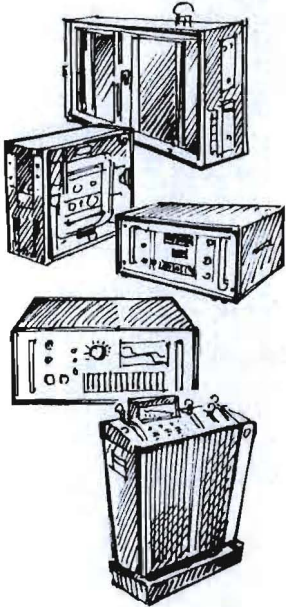
1973 The quadrophonic EMT 140 Q Reverberation Unit with four pickup transducers was introduced for creating a homogenous impression of a room.

1975 After four years of computer-supported development efforts, EMT achieved an ambitious goal: the production of reverberation by entirely electronic means with the EMT 250 Electronic Reverberation Unit, the first unit of its kind in the world.

1978 The EMT 440 was followed by the EMT 444 Electronic Audio Delay System, which featured a greater dynamic range and longer delay time. In the same year, a smaller and simplified version of the EMT 250 was first produced, the EMT 244 Digital Reverberation Unit.

1980 The EMT 251 Digital Reverberation System represented a significant improvement over the EMT 250. It is described in detail in this issue.

1981 The EMT 244 is replaced by the EMT 245 Digital Reverberator. The main advantage compared with its predecessor is an adjustable predelay time.



The EMT 252 Digital Reverberation System is the successor to the well-known EMT 251. On the basis of that standard unit, which provides local operation with potentiometers, lever switches, and LCD indication, a unit for 19" rack mounting with remote control has been developed.

Remote Control of Reverberation Parameters : EMT 252 Digital Reverberation System

DOPPL
REVER

Newly included are the 128 storage locations of the remote control. Half of these are preprogrammed with fixed programs; the other half allow free programming by the user. A tool has thereby been provided that significantly simplifies the task of finding appropriate settings quickly and repeatedly.

The fixed programs are oriented toward musical instruments and rooms. In the reverberation program, for instance, settings are provided for saxophones, stringed instruments, brass and woodwinds, solo vocalists, choirs, and background choirs, as well as for the acoustical characteristics of various-size rooms with different reverberation times.

Operation

On the main unit, only the power switch, level indicators, and two status indicators are located. After the panel section (printed with the block diagram) has been opened, the input and output levels may easily be adjusted at the front panel. Regular operation is controlled, however, entirely from the EMT 252 S Remote Control Unit. First, the program is selected. In addition to the main program for reverberation, six effect programs are provided, as follows:

DELAY: Program for delaying four signal paths, with time and

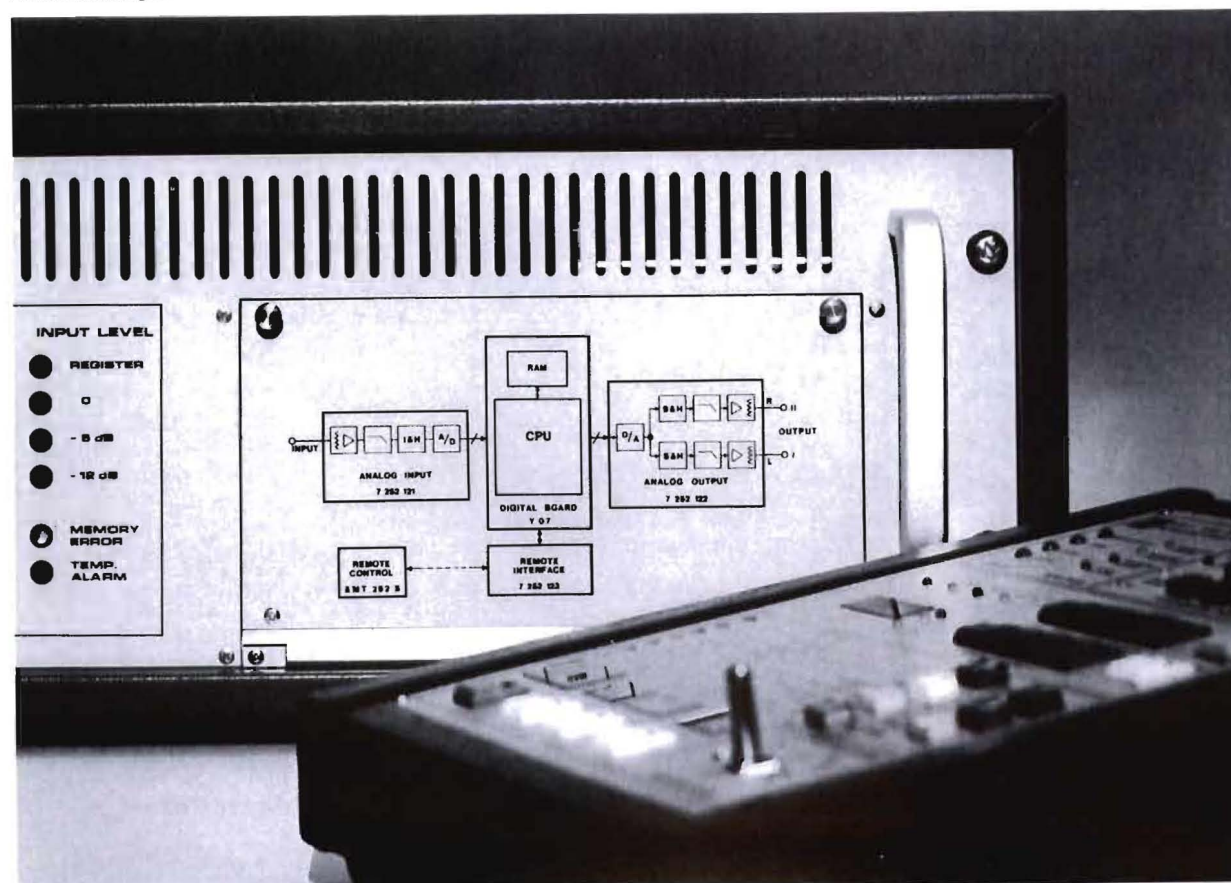
amplitude control. The maximum delay time is 480 ms.

ECHO: The repetition time and feedback factor of four echo loops may be programmed; three of the echo loops are connected in parallel behind the first loop. The longest loop duration is 440 ms.

CHORUS: Program for multiplying individual voices or instruments (orchestra effect).

NON LIN: Program with nonlinear reverberation decay curve. The signal is held nearly constant for 200 ms (very

Printed block diagram



long reverberation time); thereafter, it decays extremely rapidly (very short reverberation time). The program serves to concentrate individual voices or instruments without conveying the impression of excessive reverberation.

DOPPLER

REVERB: Effect reverberation with long reverberation times and linear frequency response of the reverberation time. Through use of

the Doppler effect (frequency shifting), an impression is created of moving sound sources within the room.

SPACE: Effect reverberation with long reverberation times and linear frequency response of the reverberation time.

The various parameters may be varied within a program by selecting the function with the appropriate button and changing the value with the parameter lever. The functions and value

ranges for buttons I through IV are provided in the table on the program selection field.

These parameters are always indicated. For the reverberation program, the value shown is the reverberation time at 1 kHz (large display) in the range 0.4 s to 4.5 s with the multiplication factors for

low frequencies (below 1 kHz)	0.5 – 2
midrange frequencies (1 kHz to 8 kHz)	0.2 – 0.9
high frequencies (8 kHz to 15 kHz)	0 – 0.9

In the middle section of the control field, the delay times and amplitudes of a number of discrete reflections may be set. (Refer to the block diagram of the REVERB program.) The amplitudes are indicated in percent ("%"), the times in milliseconds ("ms"). The reverberation time may be varied in the reverberation program between 0 ms and 80 ms; however, 40 ms may also be added to all reflections (" + 40 ms" button), so that the time range lies between 40 ms and 120 ms.

The selectable time range is indicated in the TIME SCALE field.

The PAN reflection is distributed to the two output channels with a panorama control. The adjustment is performed in 11 steps between 5 left through 0 center to 5 right.

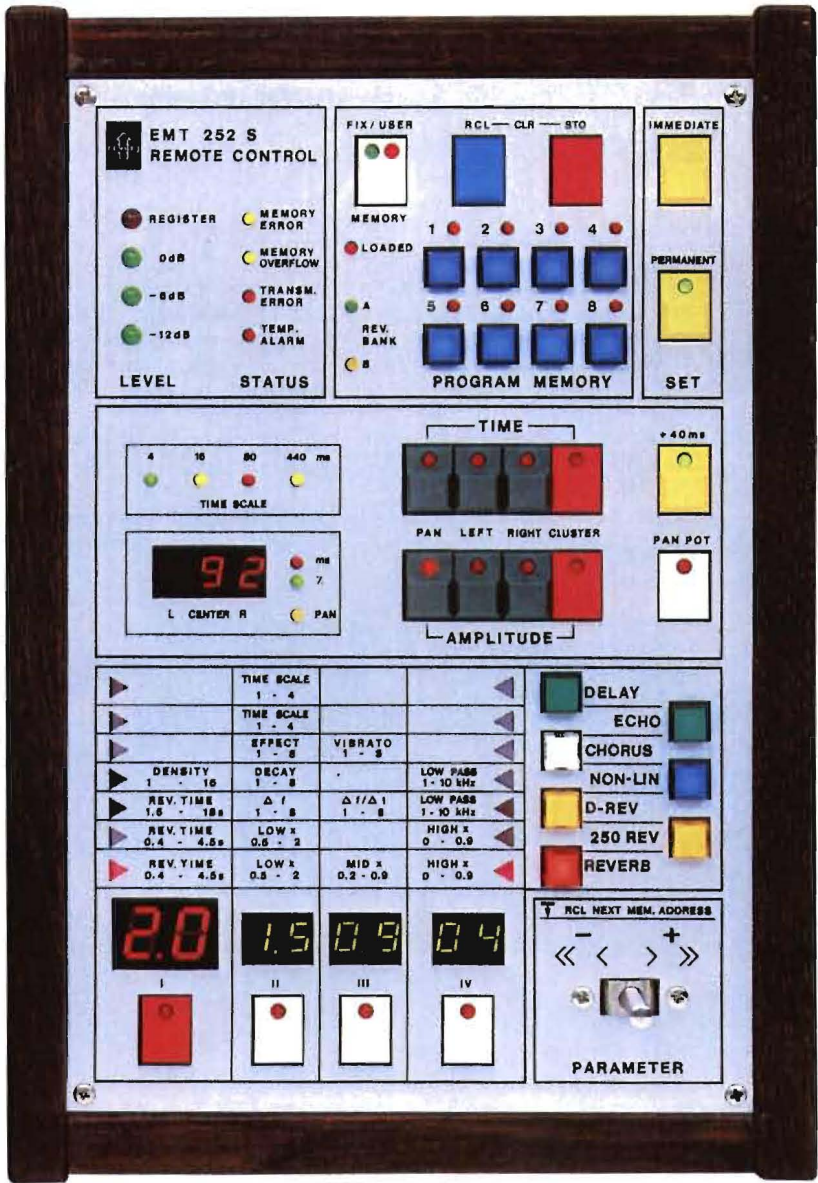
The signal path designated as CLUSTER produces a group of six reflections in a fixed relationship to one another, three of which appear in succession at each output.

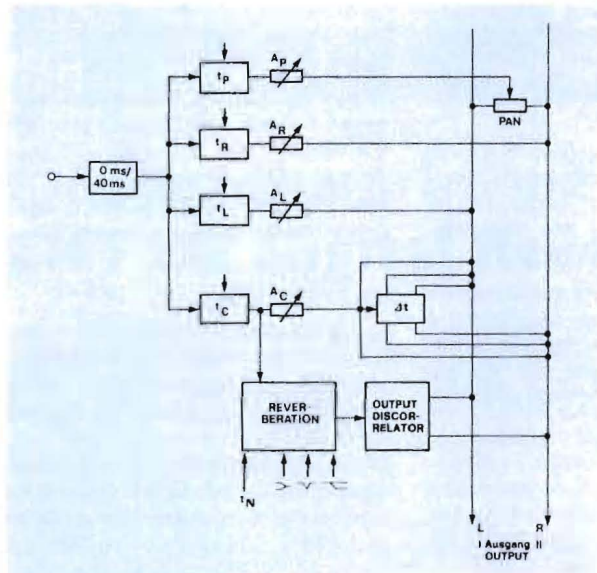
The initial delay set for the cluster is also the setting of the initial delay of the reverberation in the classical sense. Subjectively, however, the perceived initial delay depends on the relationship in time of the remaining reflections to the beginning of the reverberation.

The manifold possibilities for setting reflections allow – independent of the reverberation time – room characteristics to be simulated, such as room size, reverberation radius, distance from the sound source, strongly or weakly reflective bounding surfaces, speech intelligibility, and acoustically very asymmetrical rooms.

The fixed programs may be called up from the PROGRAM MEMORY and user settings stored. The memory is divided into the sections "FIX" (for the fixed programs) and "USER" (for the freely programmable storage positions).

EMT 252 S Remote Control Unit





Block diagram of REVERB program

For the effect programs, eight fixed programs and eight USER programs are available. For the reverberation program, 16 of each are provided. With the reverberation program, either Bank A or Bank B must be selected by pushing the selector button twice. Occupied memory positions are indicated by the "LOADED" LED.

The SET function is activated in the upper right-hand section of the control field. In the "Permanent Set" mode all parameter changes are executed immediately by the processor, while in "Immediate Set" the changes are shown on the display, but executed only when the "IMMEDIATE" button is pressed.

Particularly during the production of radio plays or films, it can be important to recall sequences of preprogrammed settings rapidly. This may be accomplished with the "PARAMETER" lever. By pressing down on the lever, the function "Recall Next Memory Position" is executed and a SET pulse automatically generated. Sequences may also be recalled in this manner by remote control, for which a foot switch may be connected.

The level indicator and several status LED's are located on the upper left. The "0 dB" LED indicates the calibrated nominal level and is set to 6 dB below the overdriving point ("REGISTER" LED). The "REGISTER" LED is also activated if the processor is overdriven.

The status LED's have the following significance:

MEMORY ERROR

An error has occurred in the dynamic RAM on the digital board, or a storage unit is defective. The error is suppressed by the automatic correction circuit and remains inaudible. A defective storage chip is indicated by a row of LED's on the digital board and thus may easily be replaced.

MEMORY OVERFLOW

In the echo program, times may be set with loops switched in series that cannot be realized in the memory. The LED then indicates that the maximum storage time has been exceeded.

TRANSMISSION ERROR

The error detection circuit has determined that an error has occurred on the transmission path between the remote control unit and the reverberation system.

TEMPERATURE ALARM

If the temperature rises excessively inside the EMT 252, the LED blinks. A recording in progress need not be interrupted, since a sufficient safety margin exists to protect the circuitry.

After the recording has been completed, however, the cause of the alarm should be investigated. Usually, either the air intake or exhaust is blocked, or one of the fans is defective.

Design and Construction

The EMT 252 Digital Reverberation System employs (as does the EMT 251) an extremely fast signal processor with bit-slice circuits. By means of "pipelining" and parallel processing, extremely rapid processing times are achieved, so that an audio bandwidth of 15 kHz with high-quality reverberation can be attained.

The unit is provided with one input and two outputs that are balanced, exhibit conventional studio impedances, and allow matching to a wide range of mixing console levels.

The audio range is limited by high-quality 11-pole Cauer filters with delay time compensation, insuring that no aliasing effects will be heard. The audio signals are converted by 16-bit

The highly accessible circuit boards of the EMT 252



convert range. formed word ler
The dyr signals plays a tion circ rors an memory tion of become position indicate
The unit The digi under tralog bo terface front pa cluded ment.
The pov justmen sible fro
The ren through The inf tones. develop data tr been en EMT 24 advanta nique li prox. - trum its 12 dB/c prevent digital s The sig and may like nor over 10
The ren croproc ton sig impleme main un
Transm tions: th are trar the rem lection to the m
The fixe grams a is buffe data are years, a to betal

deter-
l on the
remote
on sys-

ssively
inks. A
not be
safety
nity.

i com-
e alarm
, either
locked,

eration
s the
signal
its. By
parallel
ocess-
n audio
quality

ut and
exhibit
s, and
of mix-

high-
n delay
at no
he au-
16-bit

EMT 252

converters that afford a high dynamic range. Further operations are performed in the processor, in part with a word length of 20 bits.

The dynamic RAM, in which the audio signals are temporarily stored, employs a high-performance error correction circuit that can eliminate 1-bit errors and recognize 2-bit errors. The memory is organized to enable correction of all errors when a storage unit becomes inoperative. In addition, the position of the defective storage chip is indicated.

The unit is designed for easy servicing. The digital board is located horizontally under the top cover plate, while the analog board and the remote control interface have been inserted through the front panel. An extension board is included in the unit as standard equipment.

The power supply with all fuses and adjustment components is easily accessible from below.

The remote control unit is connected through a two-conductor balanced line. The information is coded in 10-kHz tones. This interface point has been developed by EMT especially for studio data transmission and has already been employed (for the first time) in the EMT 245 S Remote Control Unit. The advantages of this transmission technique lie in the low signal level of approx. -20 dB and in the signal spectrum itself, which rolls off at approx. 12 dB/octave above 10 kHz, thereby preventing the crosstalk problems of digital signals with absolute certainty. The signal contains no DC component and may be transmitted via patch fields like normal modulation. Distances of over 100 meters may be spanned.

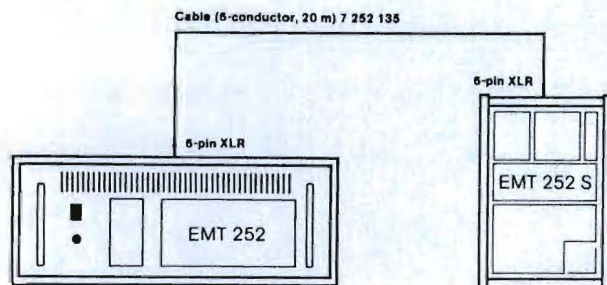
The remote control unit contains a microprocessor which interprets the button signals, drives the displays, and implements communication with the main unit.

Transmissions proceed in two directions: the level information and status are transmitted from the main unit to the remote control, while program selection and parameter values are sent to the main unit.

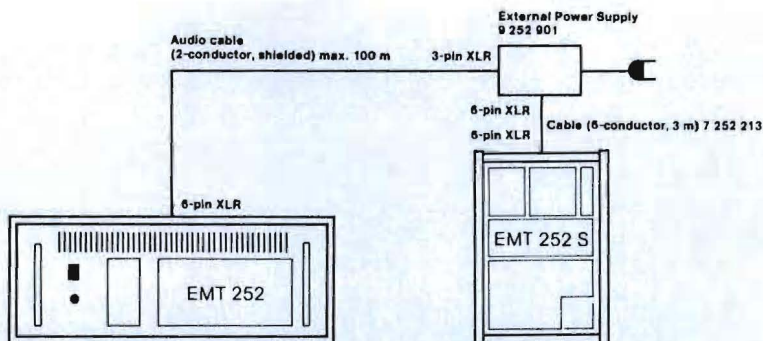
The fixed programs and the USER programs are stored in a CMOS-RAM that is buffered with a lithium battery. The data are thus protected for approx. 10 years, allowing the remote control unit to be taken into another studio.

For distances up to 20 meters, the remote control unit is connected directly to the EMT 252 Digital Reverberation System using the cable provided with the unit. Power is supplied through the cable.

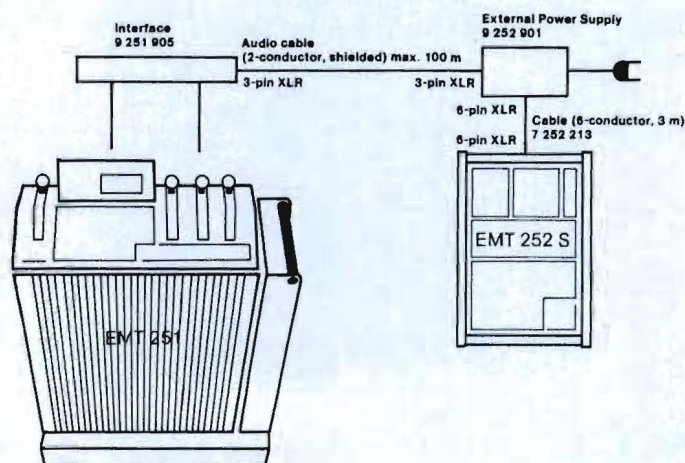
For greater distances, an external power supply must be connected ahead of the remote control unit. In addition, the remote control unit may be connected to an existing EMT 251 Digital Reverberation System. In this case, an interface and an external power supply are required.



Connection of the EMT 252 S Remote Control Unit to the EMT 252 Digital Reverberation System for cable lengths up to 20 meters



Connection of the EMT 252 S Remote Control Unit to the EMT 252 Digital Reverberation System for long cable lengths (max. 100 m)



Connection of the EMT 252 S Remote Control Unit to the EMT 251 Digital Reverberation System



ELECTRONIC, MEASUREMENT, AUDIO TECHNOLOGY
OF WORLD WIDE FAME

EMT 252

Digital Reverberation System

perfectly
natural
natural
natural
natural



GOTHAM
AUDIO CORPORATION

741 Washington Street
New York, NY 10014
Telephone 212 741-7411 Telex 236779
West Coast Office 818 785-2211